The Influence of Atmospheric Rivers on High-Latitude Wintertime Precipitation

Claire Pettersen[1], Marian Mateling[2], Tristan L'Ecuyer[2]

Collaborators: Kyle Mattingly[3], S. Joseph Munchak[4], Mareile Wolff[5]

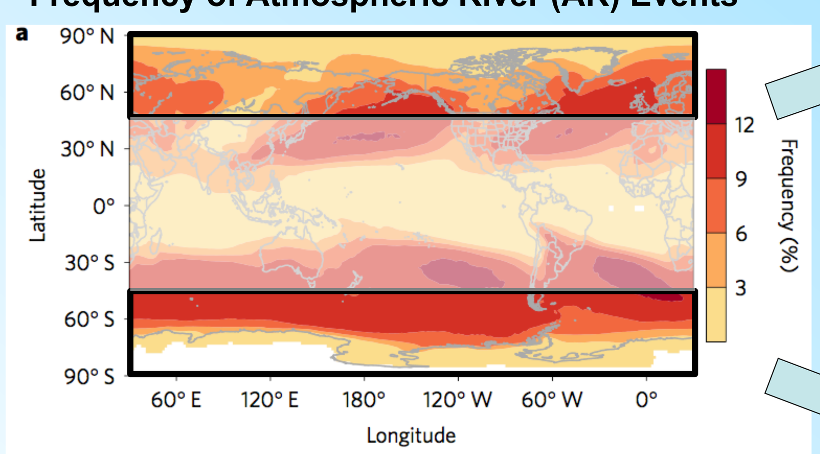
[1] University of Wisconsin-Madison, Space Science and Engineering Center, Madison, Wisconsin, claire.pettersen@ssec.wisc.edu
[2] University of Wisconsin-Madison, Atmospheric and Oceanic Sciences Department, Madison, Wisconsin
[3] Institute of Earth, Ocean, and Atmospheric Sciences, Rutgers, the State University of New Jersey, Piscataway, New Jersey
[4] NASA Goddard Space Flight Center, Greenbelt, Maryland
[5] Norwegian Meteorological Institute, Oslo, Norway

2019 PMM STM Poster Number 202

Atmospheric Rivers

Atmospheric Rivers – Extremes in Precipitation and Winds

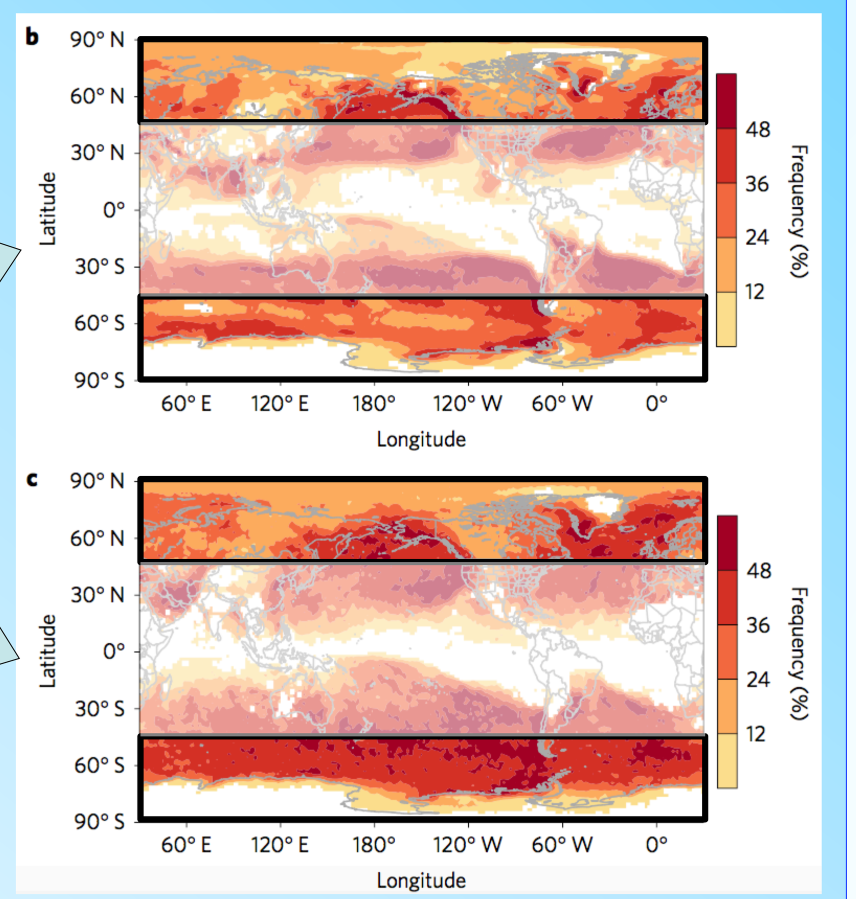
Frequency of Atmospheric River (AR) Events



Modified Figure 1 from Waliser and Guan (2017)

Extreme Winds

Extreme Precipitation



Modified Figure 1 from Waliser and Guan (2017)

In the high-latitudes (≥ 50°N/S):
- Occurrence of ARs > 10%
- ~50% AR events have extreme winds at landfall
- >40% AR events are associated with extreme precipitation

Waliser and Guan, 2017

Atmospheric Rivers – High-Latitude Detection Approach (Mattingly)

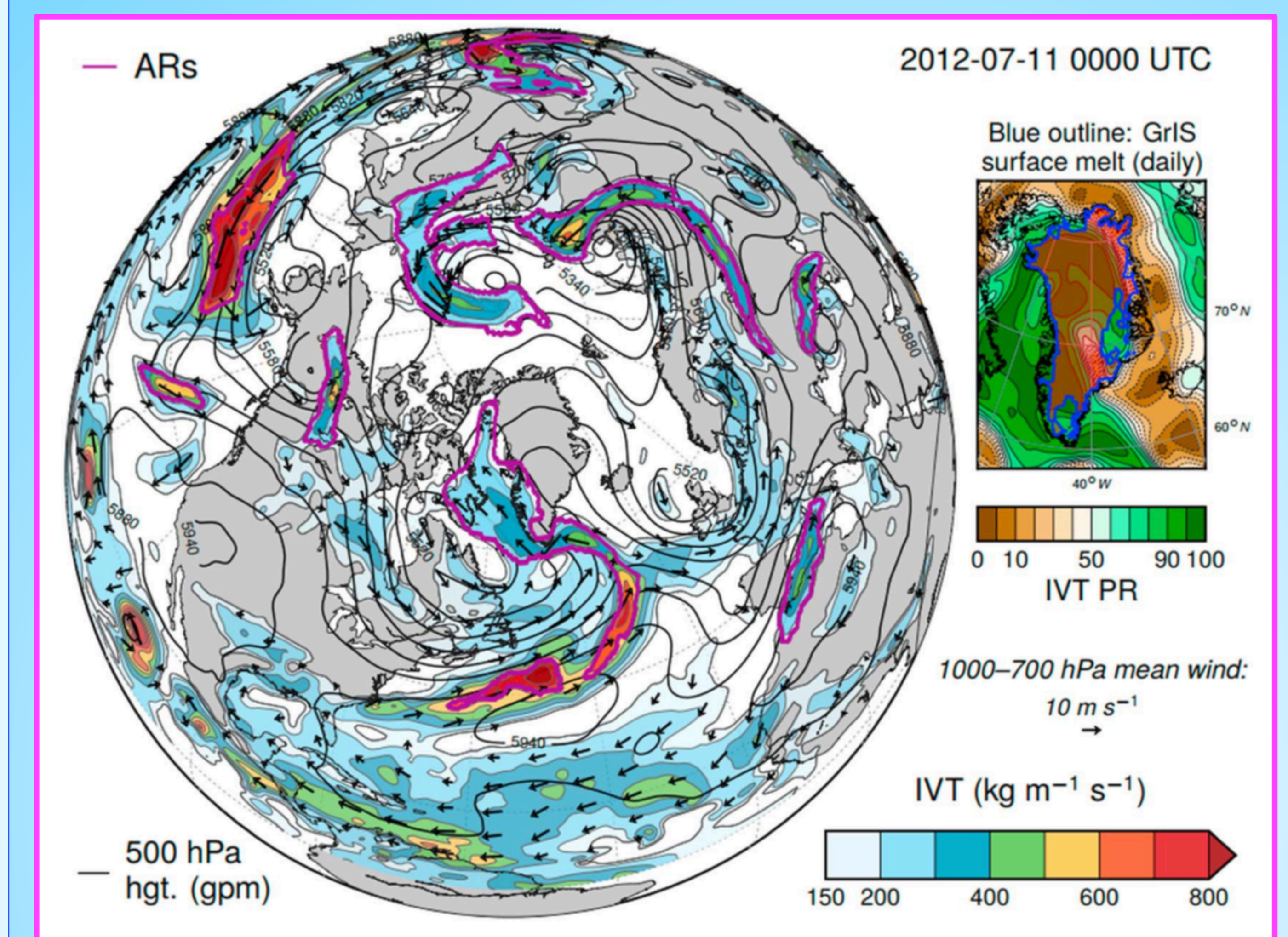


Figure 1. Example of ARs detected using MERRA-2 data at 11 July 2012 0000 UTC. Purple outlines identify features classified as ARs based on the criteria outlined in Table 1.

The Mattingly et al. (2018) detection algorithm is specifically designed to identify atmospheric rivers at in the high-latitude regions. The algorithm uses integrated water vapor transport (IVT) calculated from the MERRA-2 reanalysis and sorts the identified events by percentile rank (PR).

Table 1 (below) illustrates the criteria needed to qualify as an atmospheric river event and be included in the database. The atmospheric river catalogue covers the Northern Hemisphere from 1979 through 2018 at 6-hourly resolution.

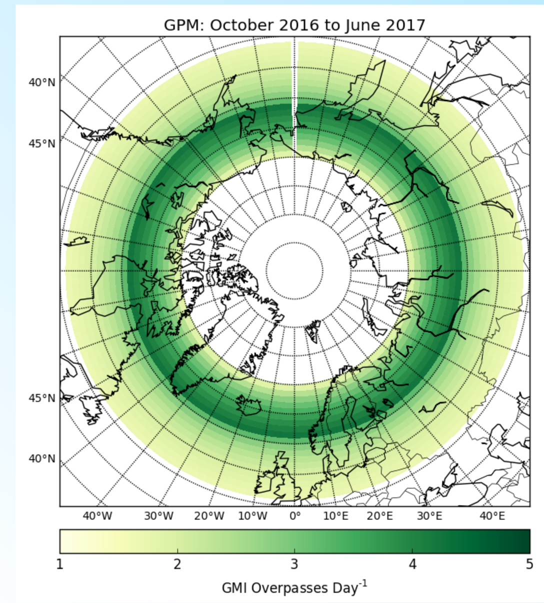
Table 1
Summary of AR Identification Criteria

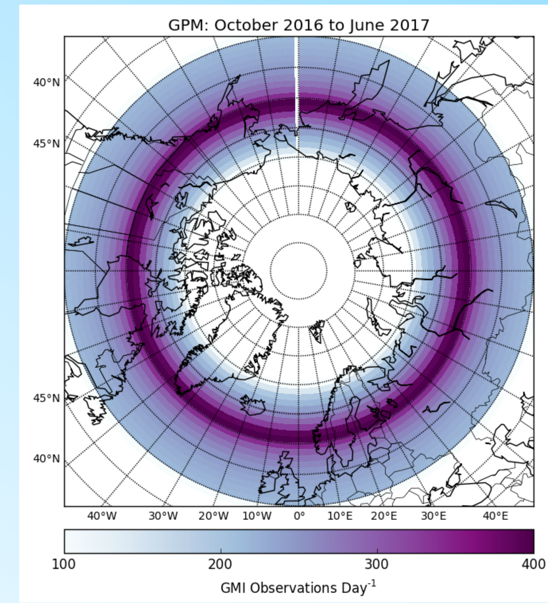
	Raw IVT	IVT PR	Minimum size	Location	Length	Length-to-width ratio	Zonal transport component	Meridional transport component
Criterion applied to potential AR objects	>150 kg m^{-1} s^{-1}	>85th %-ile	>150 reanalysis grid points (0.5° × 0.5°)	Some part of object located poleward of 10°N	>1500 km	>1.5	u wind >2 m s^{-1} (from west) if object centroid is south of 35°N	v wind >0 m s^{-1} (from south) if object centroid is south of 70°N
Purpose/ other notes	Relatively low threshold accounts for lesser magnitude of moisture transport in higher latitudes		First pass which reduces number of objects processed by algorithm in subsequent tests		Great circle distance between the two most distant perimeter points of object	"Effective Earth surface width"—object length divided by object Earth surface area	Filters out zonal tropical moisture plumes with east-to-west moisture transport	Ensures that ARs transport moisture poleward, but allows for high-latitude ARs approaching Greenland from Arctic

Mattingly et al., 2018

Advantages of GPM Orbit and GMI at High-Latitude

Concentration of GMI Observations in Northern Hemisphere

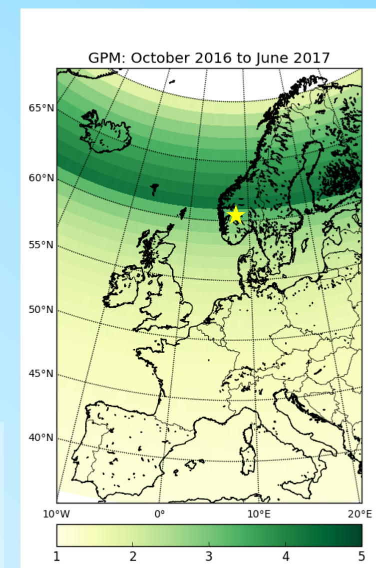


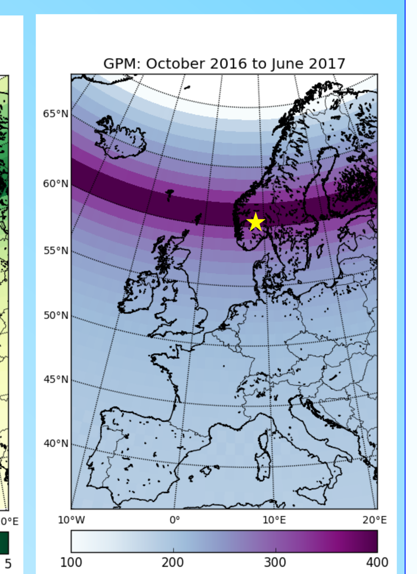


GMI at High-Latitude:
- GPM has several overpasses
  - 2 – 5 per day between 50°N and 69°N
  - Maximum at 61°N
- GMI swath width is 885 km which allows 100s of observations per day per (1°)^2
  - 200 – 400 observations per day between 50°N and 69°N
- Utilize the GMI for:
  - Precipitation (GPROF)
    - High-frequency GMI channels
  - Water vapor (RSS)

Ground Validation Capabilities in Haukeliseter, Norway

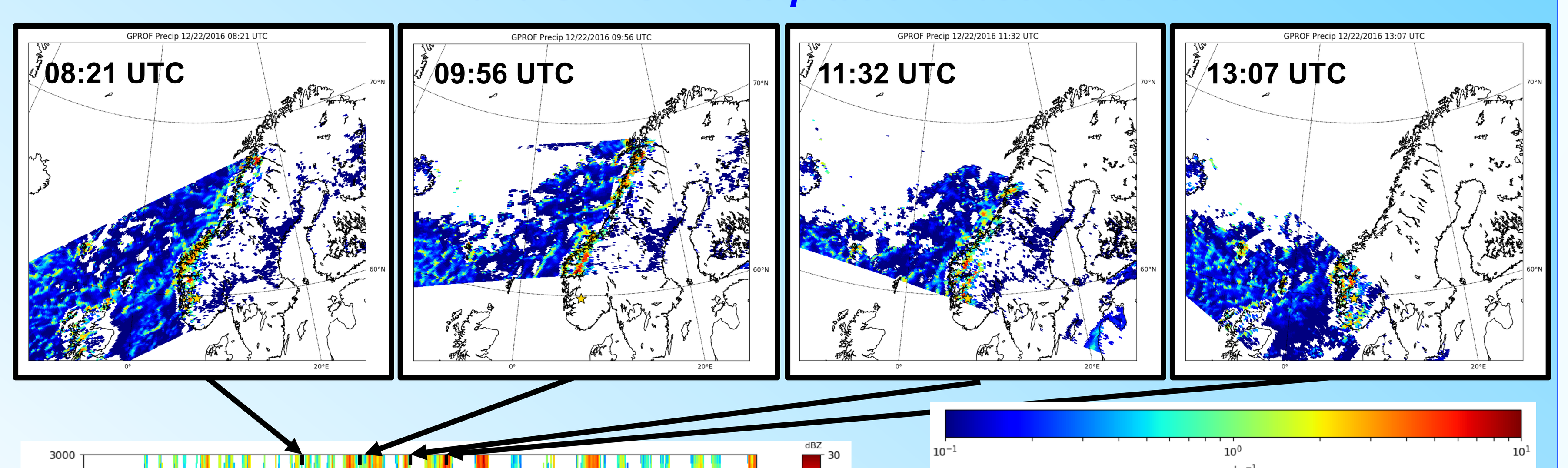
MetNorway Snow Laboratory – Location and Instruments (Wolff)

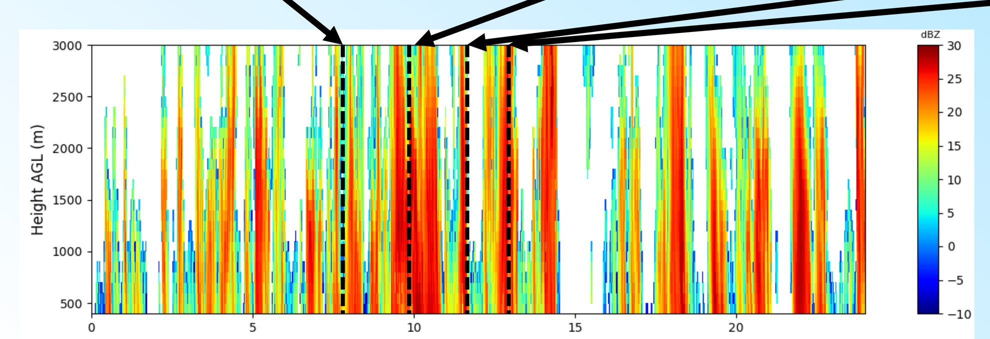




The Haukeliseter site has several accumulation gauges, including a double-fence inter-comparison reference standard. There is also meteorological and radiation observations. In winter 2016-2017, we deployed a MicroRain Radar (MRR) and a Precipitation Imaging Package (PIP). A second deployment is planned for 2020-2021.

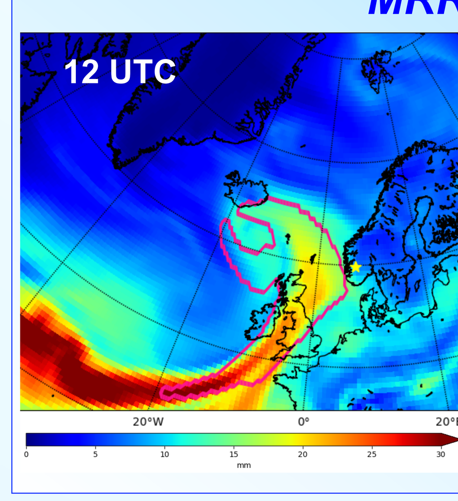
MRR and GPROF Precipitation Observations

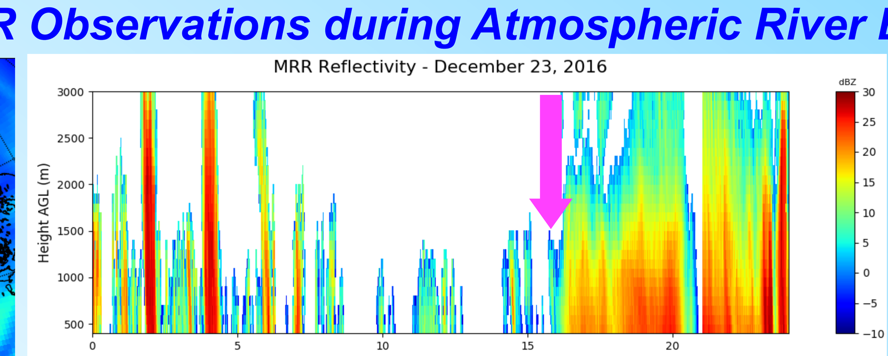


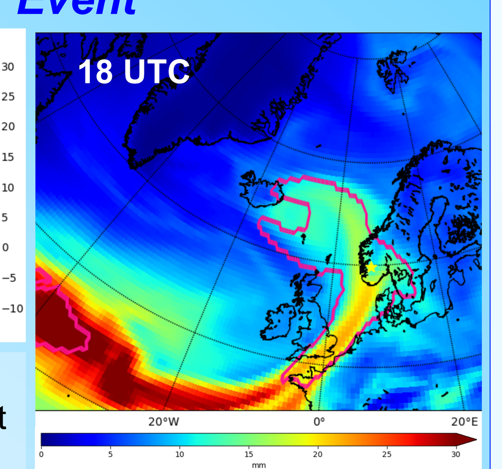


December 22, 2016 example of precipitation observed at Haukeliseter (MRR reflectivity, left figure) and from several overpasses of GPM (GPROF snow rate, top figures). The location of the snow observatory at 59.8°N is ideal for collocation of GMI observations.

MRR Observations during Atmospheric River Event





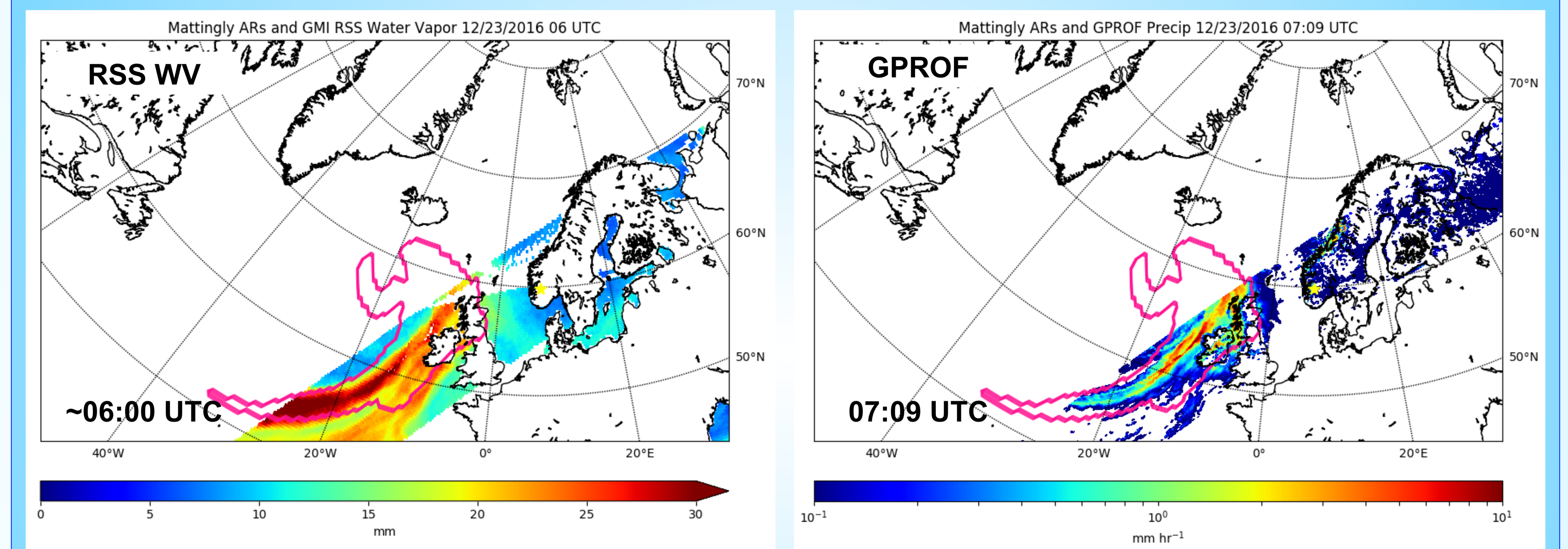


AR approaching the site, still off shore at 1200UTC.

AR impacting the site (arrow) and onshore at 1800UTC.

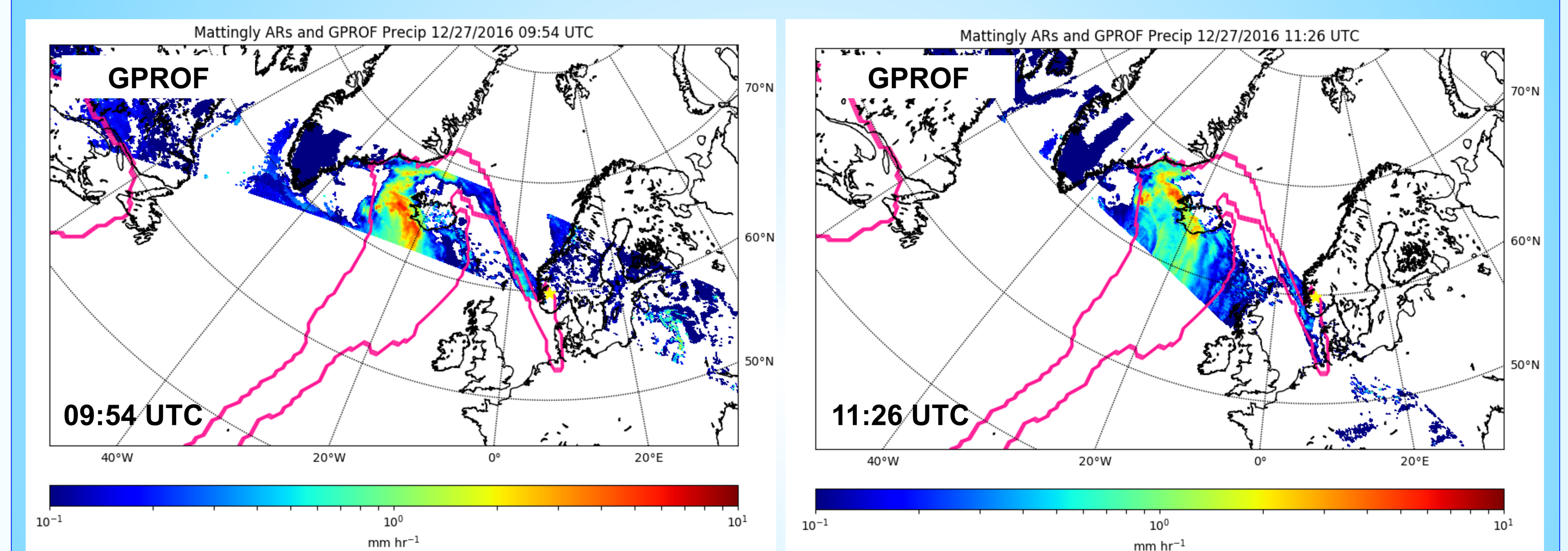
Coincident Atmospheric River Detection and GMI Observations

GMI Retrieved Water Vapor (RSS) and Precipitation Rate (GPROF)



The above figures show an identified atmospheric river (AR) event (outlined in magenta) on **December 23, 2016** at **06:00 UTC**. The GMI retrieved water vapor (RSS) from approximately 0600UTC is shown in the left figure. The highest values of water vapor are mostly within the boundaries of the AR. The GMI retrieved values of precipitation rate (GPROF) for **07:09 UTC** are shown in the right figure. Again, the highest precipitation rates are within the identified AR boundary. These collocated figured illustrate the value of examining GMI retrieved properties during AR events.

GMI Precipitation Rates during Atmospheric River Events



The above figures illustrate the GMI retrieved precipitation rate (GMI GPROF) collocated with an identified atmospheric river (AR) event on December 27, 2016 at two time steps: 09:54 UTC and 11:26 UTC. The identified region of the AR is outlined in magenta and is for the 12:00 UTC time step. Note that in both time steps, the precipitation rate, as detected by the GMI, is higher within the bounds of the AR – even in the thin filament extending towards Scandinavia. This example event highlights the utility of GPM for characterizing the precipitation during AR events.

Project Objectives

Primary Objective: This study will utilize the abundance of global GPM observations at high-latitude to quantify the character of high-impact, atmospheric river-influenced wintertime precipitation events:
- Characterize the frequency and spatial structure of atmospheric river-enhanced precipitation using GMI brightness temperatures and snow rate products and examine the temporal evolution of these extreme events
- Evaluate the accuracy of reanalysis-based atmospheric river identification methodologies for high-latitude environments with GMI water vapor products

Secondary Objective: This study will further leverage ground-based in-situ and remote-sensing instrument observations located at a high-latitude site to evaluate GMI snow estimates in select cases of precipitation associated with atmospheric rivers. These comparisons will:
- Assess estimates of the fractional snow accumulation associated with atmospheric rivers derived from GMI observations using ground-based observations, including an inter-comparison reference standard
- Evaluate the microphysical characteristics of the atmospheric river-enhanced precipitation using ground-based remote-sensed and in-situ measurements

References:

- *Waliser, D. and Guan, B., 2017. Extreme winds and precipitation during landfall of atmospheric rivers. Nature Geoscience, 10, 179.*
- *Mattingly, K.S., Mote, T.L. and Fettweis, X., 2018. Atmospheric river impacts on Greenland Ice Sheet surface mass balance. Journal of Geophysical Research: Atmospheres, 123, 8538-8560.*
- *Schirle, C.E., Cooper, S.J., Wolff, M.A., Pettersen, C., Wood, N.B., L'Ecuyer, T.S., Ilmo, T. and Nygård, K., 2019. Estimation of Snowfall Properties at a Mountainous Site in Norway Using Combined Radar and In Situ Microphysical Observations. Journal of Applied Meteorology and Climatology, 58, 1337-1352.*
- *Wolff, M., Isaksen, K., Brækkan, R., Alfnes, E., Petersen-Øverleir, A. and Ruud, E., 2013. Measurements of wind-induced loss of solid precipitation: description of a Norwegian field study. Hydrology Research, 44, 35-43.*